Inertia Sensor

1. **Field of the Invention**:

The invention relates to an inertia sensor, and in particular, to a device with inertia mass, which size may be changed, formed upon suspension structure by micro-electroplating process.

2. **Background of the Invention**:

Currently, there are roughly four kinds of manufacturing techniques in Micro Electric Mechanical System (MEMS) applied for inertia sensor: surface micromachining, bulk micromachining, LIGA process, and other micromachining techniques.

Wherein, the surface micromachining is to apply thin film deposition and etching technique of semiconductor process to manufacture MEMS elements on chips. As shown in Fig. 1, the steps for constructing suspension structure by surface micromachining may be classified as follows:

(a) Depositing isolation layer 2 upon silicon wafer 1.

(b) Depositing sacrificial layer 3 upon isolation layer 2.

(c) Etching sacrificial layer 3 using lithography process.

(d) Depositing a suspension structure layer 4 upon the sacrificial layer 3.

(e) Generating suspension structure layer 4 by removing the sacrificial layer 3.

The bulk micromachining is applying etching techniques, such as: anisotropic etching, etch-stop technology and etching mask, etc. to etch single crystal silicon to fabricate MEMS elements. As shown in Fig. 2, the steps for bulk micromachining are classified as follows:

(a) Depositing thin film layer 2 upon wafer 1.

(b) Etching thin film layer 2 by lithography process.

(c) Etching the silicon wafer 1 to generate suspension structure layer 21.

LIGA technique applies the combination processes of X-ray etching, micro plating, and injection molding to manufacture microstructure with high aspect ratio. The micromachining process is to apply the techniques of cutting machining, micro electrostatic discharge machining, or injection molding, etc., to manufacture MEMS elements.

When applying aforementioned traditional MEMS techniques to inertia sensor design, there are two confronting bottlenecks: first, the microstructure is with high aspect ratio; second, a lateral sensing and signal driving objectives must be achieved by means of small intervals within the microstructure. Currently, the bulk micromachining is mostly applied in the design of inertia sensor, but such kind of designing manner is always incurred with

the inaccurate alignment in the crystal direction of single crystal silicon substrate and the limitation in etching width. In addition, if the lateral sensing or signal driving arrangement is required, the arrangement of lateral electrodes is another troublesome problem.

As for existent etching techniques, such as: deep reactive ion etching (RIE), bulk silicon anisotropic etching, LIGA, etc., there are several shortcomings incurred:

1. For deep RIE, it is applying two major gases to protect the side wall and to etch at the same time, such that the purpose to etch the materials vertically is reached, but there are some inherent limitations on such kind of manufacturing manner technique: first, the etched materials must be silicon based, such that the purpose for protecting the side wall may be reached; if the size difference of each zone to be etched is large, the etched depths will be very differentiated as well, so it is impossible to reach equal-depth etching; in addition, although the micro intervals can be generated by the etching processes, it is impossible for other techniques to manufacture electrodes on side surfaces.

2. For bulk silicon anisotropic etching, it mostly applies the different etching speeds of etching liquid on the crystal lattice of single crystal silicon to reach the purpose of anisotropic etching, so the etching and non-etching areas defined

prior to the etching process become a crucial factor for the accurate alignment on the original crystal lattice of single crystal silicon; furthermore, controlling the etching uniformity of entire wafer is also a big problem.

3. For LIGA process, it combines the lithography, electroforming , and molding to manufacture microstructure with high accuracy and high aspect ratio; the standard LIGA technique applies synchrotron radiation X ray as lithography, and the accuracy of the microstructure may reach sub-micro level, but it is expensive and complicated, so it has developed a trend for applying ultraviolet light, laser, or plasma as light source for LIGA-like technique and, since UV lithography process incorporated with thick film photo-resist technique may realize an UV-LIGA process of low cost.

The design structure of inertia sensing system made by common MEMS technique is mainly comprised of driving, sensing, and mass block parts. For current MEMS technique, an IC thin film process is preferably adopted, but the MEMS element manufactured by IC thin film process has extremely small bearing limitation for mechanical stress, so only static products subjected none or small stress have developed, such as: acceleration gauge, force sensor, and physic sensor combined with bio-medical sensing chip, etc. In the future, MEMS will march into the field of dynamic system, so how to promote the strength for sensing signals and

how to control different sensing levels have become a very difficult challenge. Therefore, developing a high aspect ratio structure, increasing mass on suspension structure layer, and arranging electrodes on side faces are crucial factors in manufacturing an inertia micro-sensor.

As shown in Fig. 3 and Fig. 4, two inertia sensing systems made by MEMS are illustrated, wherein a bulk micromachining process is applied to form the suspension structure layers 21a, 21b and the inertia mass blocks 22a, 22b. The inertia mass blocks 22a, 22b are arranged below the suspension structure layers 21a, 21b. Since inertia mass blocks 22a, 22b are made of single crystal and non-conductive materials, so the suspension structure layers 21a, 21b and the inertia mass blocks 22a, 22b can only reciprocate up and down and can not be applied in lateral sensing or signal driving arrangement.

Summary of the Invention

According to the shortcomings of the prior arts, the main objective of the invention is to provide an inertia sensor, wherein inertia mass block is formed on suspension structure by micro-electroplating process, and the size of the inertia mass block may be changed for being adapted to sense in different levels. By selecting metal as advantageous material in the process, it

is possible to reach the objective of lateral sensing and signal driving arrangement in a microstructure of high aspect ratio.

The secondary objective of the invention is to provide an inertia sensor capable of realizing the designing goal of high aspect ratio structure, and its cost is also cheaper than that of other process of high aspect ratio.

Another objective of the invention is to provide an inertia sensor, wherein its suspension structure has conductivity, such that lateral sensing or signal driving functions may be reached.

The further objective of the invention is to provide an inertia sensor, wherein its processing temperature is low, its compatibility with other processes is high, and it may be combined to MOS to reach systematic integration.

The further another objective of the invention is to provide an inertia sensor wherein, on one hand, it has reinforcing structure for suspension structure, on the other hand, it may suppress or change the vibration mode.

Following drawings are presented to describe the detailed structure and its connective relationship according to the invention for facilitating in understanding the characteristics and the objectives of the invention.

Brief Description of the Drawings

Fig. 1 shows the steps for the surface micromachining according to prior arts.

Fig. 2 shows the steps for the bulk micromachining according to prior arts.

Fig. 3 and Fig. 4 are two structural illustrations for inertia sensing micro-system made by MEMS technique according to prior arts.

Fig. 5 is a perspective diagram for a preferable embodiment according to the invention.

Fig. 6 is a s perspective diagram for another preferable embodiment according to the invention.

Fig. 7 shows the steps for processing the suspension base structure according to the invention.

Fig. 8A and Fig. 8B show the steps for processing the micro-electroplating structure according to the invention.

Detailed Description of the Invention

Please refer Fig. 5, which shows an embodiment for an inertia sensor according to the invention. The inertia sensor 30 is comprised of a suspension structure 31 and a micro-electroplating structure 32. The suspension structure 31 has an arm 311, one side 3111 of which is connected to a supporting piece 33, and another side 3112 of which is shown as suspending state and is

extended horizontally to two sides to form a platform 312 by taking the arm 311 as center. A micro-electroplating structure 32 is respectively arranged at two sides on top of the platform 312.

Again, please refer to Fig. 6, which shows another embodiment for the inertia sensor. The inertia sensor 40 is comprised of a suspension structure 41 and a micro-electroplating structure 42. The suspension structure 41 has an arm 411, one side 4111 of which is connected to a supporting piece 43, and another side 4112 of which is shown as suspending state and is extended horizontally to two sides to form a platform 412 by taking the arm 411 as center. A micro-electroplating structure 42 is respectively arranged at two sides on top of the platform 412. The characteristic of this embodiment is that there are reinforcing structures 44, 45 arranged at the top edges of platform 412 and arm 411. Wherein the reinforcing structure 44 is located at two top sides of the arm 41 and is extended inside the platform 412 and is further connected to the micro-electroplating structure 42. The reinforcing structure 44 is made of conductive material and not only has reinforcing function but also can increase sensing area. The platform 412 located outside the reinforcing structure 45 is purely for the reinforcing function, so there is no limitation for its materials, but one thing should be noted: the reinforcing structure 45 is not connected to the micro-electroplating structure 42.

Please refer to the processing steps concerning the inertia sensor according to the invention. Thereby, the detailed disclosure of the invention may be thoroughly understood.

First, please refer to Fig. 7, which means that the invention must has a suspension-based structure 10, of which manufacturing process includes following steps:

(a) Preparing a silicon wafer 1, on which SiO_2, Si_3N_4 are provided as isolation thin film (not shown in the figures) with respect to the silicon substrate; secondly, a metallic material is chosen as electrode 23 for driving signals; then Si_3N_4 is deposited upon the silicon wafer 1 to function as isolation layer 2, on which connecting paths for signals are arranged.

(b) Sacrificial layer 3 is deposited upon isolation layer 2 through LPCVD (Low Pressure Chemical Vapor Deposition) method.

(c) Defining an etching area of sacrificial layer 3 for lithography process.

(d) A suspension structure layer 4 is formed by depositing poly-silicon on the sacrificial layer 3 through LPCVD method.

After the suspension-based structure 10 is made through aforementioned steps, a micro-electroplating structure is further processed. Please refer to Fig. 8A and Fig. 8B, which include following steps:

(a) A plating seed layer 5 is plated by lithography process upon the suspension-based structure 10, and the plating seed layer 5 may be made of Aluminum (Al) or Chromium (Cr).

(b) A thick film photo-resist 6 may be set up upon the plating seed layer 5 by lithography process.

(c) A metallic plating layer 7 is formed between the thick film photo-resists 6 by micro-electroplating process, and the metallic plating layer 7 may be made of Aluminum (Al) or Chromium (Cr), and the material of the metallic plating player 7 appropriately adopts the same material as that of the plating seed layer 5.

(d) The thick film photo-resist 6 is removed by lithography process.

(e) The plating seed layer 5 is removed by lithography process as well, and one thing must be pointed out is that the plating seed layer 5 located at bottom of the metallic platting layer 7 may be integrated with the metallic plating layer 7 as one body when the latter is under electroplating process, so no plating seed layer 5 is presented herein any more.

(f) Finally, the sacrificial layer 3 is removed by lithography process to form a suspension structure body 20 constructed by suspension structure layer 4 and metallic plating layer 7; Comparing step (f) of Fig. 8B with Fig. 5, the metallic plating layer 7 is equivalent to micro-electroplating structure

32, and the suspension structure layer 4 is equivalent to arm 311.

In summary, the invention has following advantages:

1. The size of the inertia mass of the sensor may be changed by means of the thickness variation of the metallic plating layer, such that it may be adapted for sensing function of different levels.

2. The design goal of high aspect ratio may be realized under the condition of low cost.

3. The suspension structure body has conductivity, such that lateral driving and sensing become possible.

4. The processing temperature is low, compatibility with other processes is high, and it may combine with MOS to achieve system integration.

5. Reinforcing structure may also be constructed upon the suspension structure body, on one hand, to reach reinforcing effectiveness and, on the other hand, to suppress or change the vibration mode.

However, the aforementioned description is just several preferable embodiments according to the invention and, of course, can not limit the executive range of the invention, so any equivalent variation and modification made according to the claims claimed by the invention are all still belonged to the field covered by the present invention.